

## The Additional Value of Intraoperative Angiography in Infragenicular Reconstruction

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**Objective:** To evaluate the ability of preoperative intraarterial digital subtraction angiography (IADSA) to predict the feasibility of infragenicular reconstruction and site of the distal anastomosis.

**Design:** Prospective study.

**Setting:** University Hospital

**Materials:** 45 patients with 50 ischaemic limbs, considered potential candidates for infragenicular reconstruction.

**Chief Outcome Measures:** Pre-reconstruction intraoperative angiography (IOA) was used as the gold standard. Analysis of angiograms was performed blindly and independently by a single observer. In patients who ultimately underwent primary amputation, exploration and attempted angiography of the crural and ankle vessels was performed to verify the IADSA findings.

**Main Results:** There was 87% accuracy ( $\kappa = 0.66$ ) between IADSA and IOA in differentiating between a normal, stenosed and occluded tibial artery and there was 86% accuracy ( $\kappa = 0.67$ ) in determining the adequacy of run-off into the pedal arch. IADSA had a positive predictive value of 100% to determine the feasibility of reconstruction but a negative predictive value of only 73%. After excluding those patients that IADSA deemed non-reconstructable, IADSA had a positive predictive value of 97% to determine the correct artery and 92% to determine the correct segment of artery for distal anastomosis.

**Conclusions:** IADSA could not determine when reconstruction was not possible, but in those deemed reconstructable by IADSA, the surgeon can confidently expose the appropriate artery at the appropriate level knowing the pedal run-off status in 86% of patients. IADSA should not be used to exclude reconstruction (i.e. pre-reconstruction IOA is still required in these patients) but for the remainder, IADSA can be used to plan surgical strategy without recourse to IOA.

**Key Words:** Ischaemia; Atherosclerosis; Infragenicular; Femorodistal; Digital subtraction angiography.

### Introduction

Infragenicular reconstruction has become an accepted technique for revascularising a severely ischaemic leg in which superficial femoral artery occlusive disease extends into the below knee popliteal artery and beyond. The operation can now be performed with low morbidity and mortality,<sup>1</sup> and when successful is associated with a superior quality of life<sup>2–5</sup> and is more cost effective<sup>6–9</sup> than primary amputation. The most important pre-requisite prior to operation is identification of a patent below knee vessel on which to site the distal anastomosis. The inadequacies of conventional preoperative angiography to delineate distal vessels have been well documented<sup>10, 11</sup> and

several alternative preoperative investigations such as pulse-generated run-off<sup>12</sup> and dependent Doppler insonation of ankle vessels have been proposed.<sup>10, 13, 14</sup>

Recent advances in radiological digital subtraction techniques have improved the ability to visualise calf and pedal vessels preoperatively.<sup>15, 16</sup> The aim of this study was to investigate the ability of preoperative IADSA to delineate patent calf vessels using pre-reconstruction IOA as the gold standard.

### Patients and Methods

A prospective study was performed to compare preoperative IADSA and pre-reconstruction IOA in 45 consecutive patients with 50 ischaemic limbs (48 had rest pain or tissue necrosis) who were considered

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potential candidates for infragenicular reconstruction. The criteria for inclusion into the study were as follows:

1. The patient was considered medically fit enough to undergo distal revascularisation.
2. IADSA showed that the pattern of disease was not suitable for treatment by percutaneous transluminal balloon angioplasty.
3. The proposed bypass was to an infragenicular artery.
4. Patients deemed "non-reconstructable" on IADSA would undergo exploration of crural and/or ankle vessels and IOA performed prior to primary amputation.

The aim of the study was to answer the following questions:

1. Could IADSA reliably determine whether a limb was reconstructable?
2. For patients undergoing reconstruction, could IADSA predict (i) to which artery the distal anastomosis would be made and (ii) to which tibial segment (upper, middle, lower third)?
3. What was the overall correlation between IADSA and IOA in differentiating between a normal, stenosed or occluded vessel in the upper, middle and lower segments of each vessel?
4. What was the overall correlation between IADSA and IOA in predicting the adequacy of run-off into the pedal arch?
5. If a policy of IADSA alone had been employed, what major discrepancies or problems might have occurred?

#### *Intraarterial digital subtraction angiography*

The radiologist performing IADSA was asked to provide the "best possible" images of the popliteal and crural vessels and also to demonstrate the pedal circulation. IADSA was performed using a Seldinger catheterisation technique of the distal aorta via the contralateral femoral artery. DSA was performed using a C-arm and fluoroscopy to obtain monoplanar images. The lower limb circulation was imaged following an aortic injection of contrast medium, allowing a time delay to image the pedal circulation. If the radiologist considered that the distal vessels had not been adequately imaged, the catheter was advanced over the aortic bifurcation into the ipsilateral femoral artery and further images obtained with specific emphasis on crural and pedal vessels.

#### *Pre-reconstruction intraoperative angiography*

IOA was performed in a standard manner in all patients with the surgeon aware of the IADSA findings. The below knee popliteal artery was exposed and cannulated with an 18F butterfly needle and an angiogram obtained after injection of 20ml Niopam (E Merck Pharmaceuticals, Hampshire, U.K.). If the popliteal artery was occluded, IOA was performed via the tibioperoneal trunk or a crural artery (Fig. 1). The surgeon was allowed to perform enough angiograms to allow determination of feasibility and level of reconstruction. If the IOA failed to show a patent vessel in the proximal or mid-calf, exploration of the ankle vessels was performed. If a patent vessel was not found at the ankle, a primary amputation was performed.

#### *Assessment of angiograms*

The IADSA and pre-reconstruction IOA films were reviewed independently and blindly by a consultant vascular radiologist (EMW) who was unaware of the clinical presentation or operative outcome. The IADSA and IOA films for each patient were reviewed on separate occasions to eliminate bias. The infragenicular vessels (below knee popliteal artery, tibioperoneal trunk and crural arteries) were divided into upper, middle and lower segments and scored normal, stenosed or occluded. A non-visualised artery was considered to be occluded. In addition, the run-off into the foot was scored as absent, indirect (filling of the plantar arch via collaterals) or direct (direct filling of the plantar arch).

#### *Statistical analysis*

IOA was considered to be the gold standard against which IADSA was compared. The positive predictive value (PPV) of IADSA was defined as  $TP/(TP + FP)$ , the negative predictive value (NPV) as  $TN/(TN + FN)$  and the accuracy as  $TP + TN/(TP + TN + FP + FN)$  where TP = true positive, TN = true negative, FP = false positive and FN = false negative. The correlation between IADSA and IOA is presented as the accuracy (percent agreement) together with the kappa value for the ability to:

1. Predict a normal, stenosed or occluded artery
2. Predict the run-off into the pedal arch

A kappa value of less than 0.2 denotes poor agreement, 0.21–0.4 fair agreement, 0.41–0.6 moderate



Fig. 1. IOA via the distal peroneal artery. Note poor filling of the pedal arch, but clear delineation of patent anterior tibial and dorsalis pedal arteries.

agreement, 0.61–0.8 good agreement and 0.81–1.0 very good agreement.<sup>17</sup>

## Results

### *Feasibility of reconstruction*

IADSA predicted that 39/50 ischaemic limbs (78%) would be reconstructable and 11/50 (22%) non-reconstructable. After IOA 42 limbs (84%) were successfully revascularised (distal anastomosis to the below knee popliteal = 7, tibioperoneal trunk = 2, proximal 1/3 crural artery = 14, middle 1/3 crural artery = 3 and distal 1/3 crural artery or pedal vessel = 16), while eight limbs underwent primary below knee amputation. The PPV of IADSA in determining the feasibility of reconstruction was 100% but the NPV was only 73%. The overall accuracy was 94%. There

were three major discrepancies; in each case IADSA failed to demonstrate a patent vessel below the proximal 1/3 of the anterior tibial artery. One was probably due to poor cardiac function (Fig. 2) but the causes of the other two failures are unknown.

### *Prediction of correct artery and segment for distal anastomosis*

If only the 39 limbs correctly predicted by IADSA as suitable for reconstruction are considered IADSA had a PPV of 97% for predicting the correct artery for reconstruction. The single discrepancy was failure of IADSA to demonstrate a normal anterior tibial artery overlying the fibula. IADSA had a PPV of 92% for correctly identifying the appropriate segment of artery for the distal anastomosis (Fig. 3). There were three discrepancies: failure of IADSA to demonstrate a normal anterior tibial artery overlying the fibula (see above), and two cases where IADSA misinterpreted the status of the middle 1/3 of the peroneal artery because of bone overlap and the presence of numerous collaterals.

### *Overall correlation between IADSA and IOA*

There was 88% accuracy between IADSA and IOA for determining whether the upper 1/3 of a crural artery was normal, stenosed or occluded ( $\kappa = 0.67$ ). The accuracy for the middle 1/3 segment was 87% ( $\kappa = 0.67$ ) and 87% for the lower 1/3 segment ( $\kappa = 0.77$ ). Overall the accuracy between IADSA and IOA in differentiating between a normal, stenosed and occluded artery was 87% ( $\kappa = 0.67$ ). Discrepancies usually arose because of misinterpretation of the IADSA caused by the presence of multiple collateral vessels (Fig. 4) and misinterpretation due to bone overlap.

### *IADSA, IOA and run-off into the foot*

There was 94% accuracy ( $\kappa = 0.78$ ) between IADSA and IOA in determining the run-off status of the peroneal artery into the foot. The values for the posterior and anterior tibial arteries were 86% ( $\kappa = 0.77$ ) and 78% ( $\kappa = 0.42$ ) respectively. Overall the accuracy between IADSA and IOA in determining the adequacy of run-off into the foot was 86%

(kappa = 0.66). The main discrepancies followed either misinterpretation of the IADSA images or a failure to demonstrate filling of the pedal arch on IADSA.

#### *Summary of major discrepancies*

If a policy of using IADSA alone had been adopted to determine surgical practice, discrepancies in the management of eight limbs (16%) would have occurred. Three (6%) would have been denied successful revascularisation and would have undergone unnecessary amputation. Three (6%) would have had the distal anastomosis sited proximal to a stenosis but in all three cases the stenosis was less than 50%. Two limbs (4%) would have had the distal anastomosis placed more distally than necessary.

#### **Discussion**

The inability of conventional preoperative arteriography to delineate patent distal vessels because of poor cardiac function and sedimentation of contrast medium has been well documented.<sup>10, 11</sup> Several alternative preoperative investigations have been proposed such as pulse-generated run-off<sup>12</sup> and Doppler insonation of ankle vessels.<sup>10, 13, 14</sup> Despite this it has been suggested by some authors that intraoperative angiography remains mandatory to confirm the findings of these preoperative investigations.<sup>18, 19</sup> Several methods of IOA have been described: Hickey *et al.*<sup>14</sup> perform IOA via the femoral artery in the groin whilst others expose the below knee popliteal artery and more distal crural vessels as necessary.<sup>1</sup> All of these procedures increase the already long operative time and also exposure of a popliteal artery which is



**Fig. 2.** IADSA (left) and IOA (right) in a patient with severe rest pain and pre-gangrenous changes in the forefoot. Despite numerous attempts, IADSA failed to show patent vessels in the lower calf. However, IOA clearly shows a patent anterior tibial artery throughout its length. Poor cardiac function probably accounted for the failure of IADSA to show patent distal vessels.



Fig. 3. IADSA (left) and IOA (right) in a 39-year-old diabetic patient with digital gangrene and occlusion of the crural vessels. IADSA correctly predicted that the posterior tibial artery was patent at the ankle with direct filling of the pedal circulation.

subsequently found to be diseased or occluded may incur considerable unnecessary dissection.

The advances in computerised digital subtraction angiography techniques over the last few years have led to improved preoperative visualisation of patent distal vessels.<sup>15,16</sup> In addition, greater co-operation between surgeons and radiologists has led to better understanding by radiologists that visualisation of distal vessels and run-off into the pedal arch is required in patients who may be candidates for distal reconstruction. Thus if the initial aortic injection of contrast fails to demonstrate distal vessels, the catheter should be advanced across the aortic bifurcation and as far distally into the affected limb as possible and the angiogram repeated. In addition, delayed films are often required to visualise the pedal arch. The ability to subtract the bony and soft tissue images allows better inspection of distal vessels as they cross the tibia and fibula and better interpretation of the films is often achieved if they are viewed directly on the computer screen in real time. Despite this, great care must be taken when interpreting the IADSA

films. The major reasons for IADSA discrepancies in this study were misinterpretation of the status of the upper 1/3 of the crural vessels because of large numbers of collaterals and misinterpretation of the middle 1/3 status of the peroneal and anterior tibial arteries as they overlie bony edges.

The findings of this study suggest that pre-reconstruction IOA is still required in some patients undergoing distal bypass. In particular, if the preoperative IADSA does not show distal vessels, it is essential to explore the below knee popliteal artery, crural and pedal arteries and perform IOA to confirm the findings of the IADSA before resorting to amputation. IOA via a crural artery may delineate, by cross-filling, other crural arteries not seen on IADSA (Fig. 1), thus allowing a degree of choice in deciding which is the best vessel for the distal anastomosis. In three limbs in this study, IOA demonstrated patent distal vessels that IADSA failed to show and all three patients underwent successful revascularisation. However, in our experience, if the IADSA shows a good quality patent below knee vessel, then it can be

confidently exposed and a distal bypass sited upon it, without the need to confirm these findings by IOA. Using this policy, three limbs in this study would have had the distal anastomosis placed proximal to a crural artery stenosis; but in all cases the stenosis was less than 50% and unlikely to compromise the bypass.<sup>20</sup> In addition, such lesions could be treated at a later date by percutaneous transluminal angioplasty<sup>21</sup> and it is possible that in future they may be treated by intraoperative balloon angioplasty.

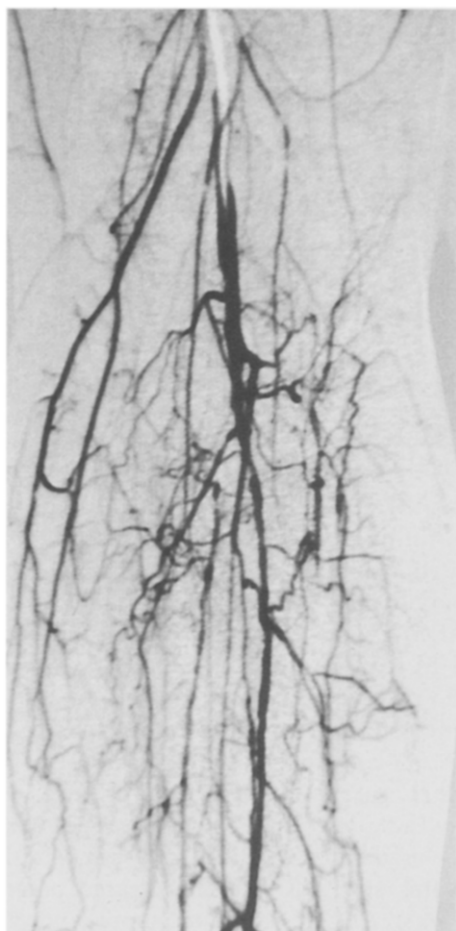
After completion of the bypass, it is essential to perform some form of completion assessment. We prefer intraoperative completion angiography of the distal anastomosis and run-off vessels via direct graft puncture but alternative forms of assessment, such as measurement of flow with an intraoperative Doppler flowmeter,<sup>22</sup> are also available.

In summary, advances in IADSA and greater understanding and co-operation between vascular surgeon and radiologist have improved the ability of

IADSA to delineate below knee vessels in patients who are candidates for infragenicular bypass. If the IADSA shows a good quality distal vessel then infragenicular bypass can be performed without the need for pre-reconstruction IOA. However, IADSA cannot be relied upon to exclude the feasibility of reconstruction and in these cases where IADSA fails to show patent distal vessels, IOA remains essential to avoid unnecessary amputation.

## References

- 1 SAYERS RD, THOMPSON MM, LONDON NJM, VARTY K, NAYLOR AR, BUDD JS, RATLIFF DA, BELL PRF. Selection of patients with critical limb ischaemia for femorodistal vein bypass. *Eur J Vasc Surg* 1993; 7: 291–297.
- 2 ALBERS M, FRATEZI AC, DE LUCCIA N. Assessment of quality of life of patients with severe ischaemia as a result of infrainguinal arterial occlusive disease. *J Vasc Surg* 1992; 16: 54–59.
- 3 HUMPHREYS WV, EVANS F, WILLIAMS T. Quality of life after vascular surgery. *Irish J Med Sci* 1992; 161: 15(suppl).
- 4 SHEARMAN CP, ASHLEY EMC, GWYNN BR, SIMMS MH. Rehabilitation of patients after vascular reconstruction for critical limb ischaemia. *Br J Surg* 1990; 77: A346.
- 5 OURIEL K, FIORE WM, GEARY JE. Limb threatening ischaemia in the medically compromised patient: amputation or revascularisation. *Surgery* 1988; 104: 667–672.
- 6 MACKEY WC, McCULLOUGH JL, CONLON TP *et al.* The costs of surgery for limb threatening ischaemia. *Surgery* 1986; 99: 26–35.
- 7 GUPTA SK, VEITH FJ, ASCER E, WHITE FLORES SA, GLIEDMAND ML. Cost factors in limb threatening ischaemia due to infrainguinal arteriosclerosis. *Eur J Vasc Surg* 1988; 2: 151–154.
- 8 CHESHIRE N, NOONE M, DAVIES L, DRUMMOND M, WOLFE JHN. Economic options and decision making in the ischaemic lower limb. *Br J Surg* 1991; 78: 371.
- 9 FRIEDMAN SG, KERNER BA, FRIEDMAN MS, MOCCIO CG. Limb salvage in elderly patients: Is aggressive surgical therapy warranted? *J Cardiovasc Surg* 1989; 30: 849–851.
- 10 CAMPBELL WB, FLETCHER EL, HANDS LJ. Assessment of the distal lower limb arteries: A comparison of arteriography and Doppler ultrasound. *Ann R Coll Surg Engl* 1986; 68: 37–39.
- 11 SCOTT DJA, HUNT G, BEARD JD, HARTNELL GG, HORROCKS M. Arteriogram scoring systems and pulse-generated run-off in the assessment of patients with critical ischaemia for femorodistal bypass. *Br J Surg* 1989; 76: 1202–1206.
- 12 BEARD JD, SCOTT DJA, EVANS JM, SKIDMORE R, HORROCKS M. Pulse-generated run-off: A new method of determining calf vessel patency. *Br J Surg* 1988; 75: 361–363.
- 13 THOMPSON MM, SAYERS RD, BEARD JD, HARTSHORNE T, BRENNAN JA, BELL PRF. The role of pulse-generated run-off, Doppler ultrasound and pre-operative arteriography in the assessment of patients prior to femorocrural bypass grafting. *Eur J Vasc Surg* 1993; 7: 37–40.
- 14 HICKEY NC, THOMSON IA, SHEARMAN CP, SIMMS MH. Aggressive arterial reconstruction for critical lower limb ischaemia. *Br J Surg* 1991; 78: 1476–1478.
- 15 POND GD, OSBORNE RW, CAPP MP *et al.* Digital subtraction angiography of peripheral vascular bypass procedures. *AJR* 1982; 138: 279–281.
- 16 TURNIPSEED WD, DETMER DE, BERKOFF HA *et al.* Intraarterial digital angiography: A new diagnostic method for determining limb salvage bypass candidates. *Surgery* 1982; 92: 322–327.
- 17 LANDIS RJ, KOCH GG. The measurement of observer agreement for categorical data. *Biometrics* 1977; 33: 159–174.
- 18 BELL PRF. Femorodistal grafts—Can the results be improved? *Eur J Vasc Surg* 1991; 5: 607–609.



**Fig. 4.** IADSA showing numerous collateral vessels arising from the below knee popliteal artery. Such collaterals often caused difficulties in interpreting the IADSA findings.

- 19 PATEL KC, SEMEL L, CLAUS RH. Extended reconstruction rate for limb salvage with intraoperative pre-reconstruction angiography. *J Vasc Surg* 1988; 7: 531-538.
- 20 VEITH FJ. Femoro-popliteal-tibial occlusive disease. In: *Vascular Surgery: a Comprehensive Review* (4th ed). Harcourt-Brace, Philadelphia 1993 (pp 465-489).
- 21 BOLIA A, SAYERS RD, THOMPSON MM, BELL PRF. Subintimal and intraluminal recanalisation of occluded crural arteries by percutaneous balloon angioplasty. *Eur J Vasc Surg* 1994; 8: 214-219.
- 22 BEARD JD, SCOTT DJA, SKIDMORE R, BAIRD RN, HORROCKS M. Operative assessment of femorodistal bypass grafts using a new Doppler flowmeter. *Br J Surg* 1989; 76: 925-928.

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